

Field Evaluation of Simulated Aerial Application Spray System to Test
Candidate Insecticides for the Control of Western Spruce Budworm,
Choristoneura occidentalis Freeman.

FINAL REPORT

Principal Investigator:

Charles E. Richmond, Research Biologist

Pacific Southwest Forest and Range Experiment Station

P. O. Box 245

Berkeley, California 94701

(415) 486-3185 or 3373

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1. Summary

Two new spray systems which simulate aerial applications of candidate chemicals for control of western spruce budworm were tested using the recommended dosage of acephate on small, naturally infested Douglas-fir and subalpine fir. Results showed both systems adequately simulated aerial application according to the testing criteria, by causing a budworm population reduction of 90% or better. Additional information is included on the effectiveness of Bolstar, UC-51762 and SIR-8514 as potential chemical control agents.

Bolstar caused a population reduction of 86.2% at 22.4 g a.i./liter and UC-51762 caused a reduction of 98% at 45 g a.i./liter, each chemical delivered at a rate of 4.1 liters/hectare (approximately .5 gal/acre). SIR-8514 did not significantly reduce the population at any of the dosages tested.

2. Introduction

A. Justification: The need for an intermediate field bioassay between the normal laboratory screening operation and small-scale aerial application has been recognized by many researchers in the field of efficacy testing. The purpose is to provide valuable, predictive information on potential effective application rates for the various candidate insecticides to be tested under field conditions. With the increasing cost of conducting small-scale aerial tests, this research would make it possible to narrow the selection of insecticides for further field testing to the most promising candidates and application rates, and reduce the probability of an inconclusive field test. Laboratory bioassays alone cannot provide this information.

Equipment and techniques for simulating aerial sprays on small naturally infested trees were developed for field evaluation of insecticidal treatments to suppress populations of defoliating insects like the western spruce budworm, Choristoneura occidentalis (Freeman). This concept was originally utilized by entomologists in the Canadian Forestry Service and has been used in

their chemical evaluation program for several years (Hopewell 1973, 1975, 1977; Hopewell and Nigam 1974; Nigam and Hopewell 1973).

Two improved systems were developed for more accurate simulation of aerial sprays. These systems were evaluated under field conditions on the western spruce budworm infested Douglas-fir, during the summer of 1979 on the Gallatin National Forest near Bosman, Montana, using the insecticide acephate (Orthene^R 75S, an organophosphate) as a test standard. This report describes that evaluation, and the effects of spraying three candidate insecticides (Bolstar^R 6E, an organophosphate; UC-51762 4F, a carbamate; and SIR-8514, an insect growth regulator) at four concentrations.

B. Objectives: (1) To evaluate the performance of two spray systems under field conditions, and enhance the development of technology to simulate aerial application, and (2) To test the relative field efficacy of Bolstar, UC-51762, and SIR-8514, as control agents for western spruce budworm, and gain valuable field experience with these new materials.

3. Methods

A. Evaluation of Simulated Aerial Spray Systems: Acephate was used to evaluate the performance of two simulated aerial spray systems under field conditions. This insecticide was chosen because it has been thoroughly tested in the field by aerial application (Markin, 1979), and is registered by the EPA for use against the western spruce budworm.

The recommended dosage rate of 60g ai/liter/ha (0.5 lb/gal/acre) was used with 0.1% Rhodamine Extra S dye added as a marking agent. Sixty small, (1.2 to 3.4 m), naturally-infested Douglas-fir trees were established as single tree plots in the Cache Creek drainage, 38 kilometers southeast of Bozeman, Montana, on the Gallatin National Forest.

The two simulated aerial application systems were developed by investigators in Forest Service laboratories in Berkeley, California, and Corvallis, Oregon. The system developed at Berkeley (Richmond's system) was

designed primarily for spraying conventional chemical agents and the system developed at Corvallis (Orchard's system) was designed for microbial sprays. Both systems are similar in design and operation.

The first experiment consisted of 20 trees randomly assigned to be sprayed with each spray system and the remaining 20 trees to serve as controls. Prior to spraying, each system was calibrated to deliver 15-20 drops/cm², with a VMD^{1/} of approximately 135 μm, and approximately 4.7 liters/ha. These values were picked as being most representative of normal aerial sprays of acephate under normal forest conditions (Pat Shea and George Markin, personal communication).

The criteria for selection of test trees were evidence of considerable previous years defoliation, accessibility, uniformity of size, amount of foliage and distance from adjacent overstoried trees. Western spruce budworm populations were monitored for each tree using the methods described by Carolin and Coulter (1972). Spraying commenced when 50% of the larvae had reached 4th and 5th instars. The prespray population estimates for this experiment were approximately 9 larvae/100 buds, which is somewhat lower than the 14.5 larvae/100 buds reported (Markin 1979) in previous aerial tests.

A portable enclosure with an area of 5.95 m² was erected around each tree, prior to spraying. The purpose of this enclosure was to provide a protective environment around the test tree; minimizing drift and containing the spray to a known area. To evaluate our ability to generate a droplet density of 15-20 drops/cm² spray coverage and droplet spectrum was assessed by placing 4 kromekote cards in four opposing directions within the enclosure about 1 m off the ground. Cards were analyzed by a Quantimet 720, an

^{1/} VMD = volume median diameter which describes the midpoint of the droplet spectrum: half of the volume is in drops smaller than this value and half is in larger drops.

electronic spot counting device at the University of California, Davis, Facility for Advanced Instrumentation. Volume delivered/unit area was calculated from the amount of insecticide applied. The mortality and spray coverage data were compared for each spray system to evaluate the success of each at effectively simulating aerial application.

Mortality assessments were determined according to the procedures originally described by Carolin and Coulter (1972). The number of living larvae per 100 buds (new growth) on six 38 cm branches was tabulated. Two branches were sampled just prior to spraying and four branches were sampled between 14 and 16 days post treatment. Sample branches were cut with hand clippers directly into a labelled brown paper market bag. In a field laboratory, larvae were removed by beating the branches against a 1.27 cm² wire mesh screen, contained in a 114 liter garbage can according to the sample technique described by Martineau and Benoit (1973). Data recorded consisted of the number of budworm larvae and pupae per branch and the total number of buds or new growth shoots. Mortality was expressed as the percent reduction between prespray and postspray populations.

B. Effects of Bolstar UC-51762 and SIR-8514 on Larvae of Western Spruce

Budworm: An additional experiment was conducted using the spray system developed by Richmond. The purpose of this experiment was to evaluate the effects of Bolstar^R, UC-51762, and SIR-8514 at four different concentrations on larvae of the western spruce budworm. The location of this study was approximately 2 km west of the first study area, and about 200 meters east of the Battle Ridge Campground. Fifty-two trees were selected from a mixture of both Douglas-fir and subalpine fir. The same criteria were used in the selection of test trees for the first experiment. Each of the four concentrations was replicated 5 times for each chemical. Twelve trees were designated as controls. Assignment of the test trees to the treatments was randomized. Selection of the dosage rates for Bolstar and UC-51672 was based

on a laboratory bioassay by Robertson and Haverty (1980). As in the first experiment 0.1% Rhodamine Extra S dye was added as a marking agent. The trees were sprayed in the same manner as previously described, except that in this experiment the spray system was thoroughly flushed with alcohol between treatments.

Prespray larval populations were slightly higher than in the first experiment, the overall mean was 12 larvae/100 buds. Prespray and postspray population estimates and spray coverage data were obtained using the same techniques previously described. As in the first experiment, the sprayer was calibrated to deliver 15-20 drops/cm² enclosure for each treated tree.

4. Results

A. Results of Evaluation of Simulated Aerial Spray Systems: In the first experiment the mean percent population reduction was 88% for Richmond's system and 85% for Orchard's system. Check mortality was 27%. Population reduction values for the treatments were not corrected for check mortality. In order to test the effectiveness at simulating an aerial application a null hypothesis was constructed, which stated that the simulated aerial application systems caused a 90% reduction in larval western spruce budworm populations under the prescribed conditions. The null hypothesis was accepted when the confidence limits of the mean population reduction value included the theoretical 90% population reduction value. The null hypothesis was accepted for both spray systems.

To test the sensitivity of detecting small differences in population reductions a power of t-test was constructed at differences of either 5 or 10 percentage points below 90%. Results showed Richmond's system to be somewhat more precise than Orchard's system under these experimental conditions (Table 1). There are, of course other logistical factors which also must be considered before determination of the best system can be made. The Orchard

system, for example, had many logistical advantages which resulted in the ability to treat more trees per day than the Richmond system. Many of these advantageous attributes will be incorporated in future models of the Richmond system.

The mean number of droplets per cm^2 and the actual amount of insecticide sprayed into the test enclosure are shown in Table 1. The overall mean value for the experiment was 19 drops/ cm^2 . The sprayer developed by Richmond can deliver different volumes of spray on each run depending on the circumstances. The mean volume delivered was 3.93 liters/ha interpolated from the actual volume measured in milliliters per 5.95 m^2 (approximately 1/2 gal/acre). The Orchard system delivered a constant 3.36 liters/ha/tree. Note that this value approximates the amount of spray received at ground level, not the amount released by an aircraft. In most cases the amounts we sprayed into our enclosure were approximately 1/2 the amounts normally released by aircraft. This amount was determined by measuring the volume of spray necessary to completely cover the test area with a droplet spectrum of between 15 and 20 drops/ cm^2 .

B. Results of Spraying Bolstar, UC-51762 and SIR-8514 on Larvae of Western Spruce Budworm: The mean percentage population reductions are shown in Table 2. The results of SIR-8514 are not included because there was no significant difference between pretreatment and post treatment population levels at any of the concentrations tested. As in the first experiment a null hypothesis and power of t-test was constructed to determine which concentration effectively achieved the 90% population reduction threshold. It is apparent from looking at the power of t statistic in Table 2, that more replications were necessary. This was the first attempt at using this equipment to evaluate candidate insecticides and we could only guess at the minimum number of replications necessary to achieve accurate results. Future testing of new chemicals using this system will require a minimum of 15 replications per concentration.

Despite the lack of sufficient replications the data suggest that both Bolstar and UC-51672 have potential for controlling western spruce budworm. Bolstar applied at a concentration of 22.4g ai/liter and delivered at 5.3 liters per hectare resulted in a 86.2% reduction in larval population. UC-51672 resulted in population reductions statistically equivalent to 90% at all concentrations. It would appear however, the concentration needed to achieve a 90% population reduction would actually be somewhere between 22.4 and 45 gram ai/liter.

C. Significance and Interpretation of Results: The usual aircraft spray delivery rate for most aerial spray operations in the Forest Service is 9.35 liters/hectare (1 gal/acre). This rate, depending on the chemical and droplet size (VMD) produced by the spray nozzle, should theoretically result in a value of between 15-20 crops/cm² as recorded on the ground. In actual practice, however, 50% or more of the spray volume can be lost to drift or evaporation, and exact measurements on the actual deposit of insecticide delivered to the target is difficult. Many factors can influence the deposit: wind, aircraft speed and elevation, volatility of the insecticide and its solvent, drop size, temperature, and relative humidity.

We recognize it is somewhat simplistic to say that actual aerial application is simulated with 100% accuracy. These new spray systems are used to generate deposits on small trees that approximate the deposit of an aerial application in terms of drop density and VMD. The strength of these systems is that they allow the researcher to deliver precise, highly reproducible spray deposits, and thus maximized the predictability of field trials. From this study insecticides will be evaluated in a relatively inexpensive field bioassay and should increase the probability of a successful large scale field test.

5. Suggestions For Additional Research

The preliminary experimental data on Bolstar and UC-51762 suggest their

possible effectiveness in reducing spruce budworm populations at relatively low dosages, but also points out the need for additional replications in future tests. Since Bolstar has been field tested in 1980 it probably needs no further testing. UC-51762, however, should be tested again with no less than 15 replications per concentration to determine the minimum effective concentration and recommended concentrations for future aerial application tests.

6. Manuscripts planned

A technical manuscript entitled "Evaluation of candidate chemical control agents for the western spruce budworm (Lepidoptera:Tortricidae) by simulated aerial applicaton", has been prepared for submission to the Canadian Entomologist.

7. Appendix: References Cited

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Table 1. Mean percent reduction of western spruce budworm larval populations as a result of spraying small infested Douglas-fir trees with acephate at 60 g ai/liter with either of two spray systems which simulate aerial application.

Spray System ^{1/}	Population Reduction ^{3/}	Null Hypothesis ^{3/}	Power of t-test ($\alpha = .05$) ^{4/}		Drops/cm ² /5/ ^{5/}	Amount Sprayed/ha
			<u>80%</u>	<u>85%</u>		
Richmond's						
	88% (9)	Accepted	.997	.79	19 (2)	3.93
Orchard's						
	85% (16)	Accepted	.83	.40	22 (3.7)	3.36

^{1/} Each treatment replicated 20 times.

^{2/} Mean (standard deviation). Data based on counting numbers of living larvae & pupae per 100 buds. Pre-spray value determined just prior to spraying, postspray value determined between 14-16 days post treatment. Larval population decreased by 27% on check trees.

^{3/} Theoretical percent population reduction threshold for effective aerial application of insecticides is 90%. Null hypothesis is accepted when this theoretical value falls within the confidence interval.

^{4/} Power of t-test is the probability of detecting the differences of 5 or 10% (Owen, 1962).

^{5/} Mean (standard deviation). Both systems were calibrated to deliver 15-20 drops/cm².

Table 2. Mean percent reduction of western spruce budworm larval populations as a result of spraying one of four concentrations of either Bolstar or UC-51762 on small, naturally-infested coniferous trees with a spray system which simulates an aerial application.

Treatments (g a.i./l)	Population reduction ^{1/2/}	Null Hypo- thesis ^{3/}	Power of t-test ($\alpha = .05$) ^{4/}		Drops/cm ² ^{1/}	Amount sprayed/ha ^{1/}
			<u>80%</u>	<u>85%</u>		
<u>Bolstar</u>						
37.5	89.4 (19)	accepted	.26	.15	18.0 (5.0)	4.4 (.2)
22.4	86.2 (9)	accepted	.70	.26	18.0 (1.2)	5.3 (.4)
11.3	49.0 (34)	accepted	.15	.08	24.5 (4.0)	5.4 (.3)
6.0	34.0 (31)	rejected	-	-	16.0(2.7)	5.6 (.1)
<u>UC-51762</u>						
90	100.0 (0)	accepted	-	-	16.0(2.0)	4.5 (.3)
45	98.0 (13)	accepted	.84	.60	20.0(2.4)	4.1 (.3)
22.4	74.0 (34)	accepted	.15	.08	16.0(4.0)	4.3 (.2)
6.0	75.0 (29)	accepted	.18	.11	13.0(3.0)	4.7 (.3)

^{1/} Mean (standard deviation). Each mean is the result of 5 replications.

^{2/} Larval populations decreased by 14% on check trees.

^{3/} The threshold for effective aerial application of insecticides is 90%. Null hypothesis is "mortality resulting from simulated aerial application is greater than or statistically equal to the threshold 90% value."

^{4/} Power of t-test is probability of detecting differences of 10 and 5% below the 90% value (one-tailed test).